

ACTIVITY: Evolution by Means of Natural Selection

Recall that in *On the Origin of Species by Means of Natural Selection*, Charles Darwin put forth his idea that evolution proceeded by means of natural selection. This idea can be distilled down into four main tenets:

1. **Overproduction:** Organisms have the capacity to produce large numbers of offspring.
2. **Variation:** These offspring exhibit variable heritable traits.
3. **Competition:** These offspring must compete for limited resources in the environment.
4. **Differential Reproduction:** Those offspring whose physical traits enable them to best exploit resources in the environment will leave more offspring than those less well adapted.

Of the five factors that can change Hardy Weinberg equilibrium, *only natural selection results in a population better adapted for survival in its particular habitat.*

The results of natural selection are everywhere around you. The warning (= **aposematic**) coloration of a stinging bee, a woodpecker's bill, perfectly shaped to extract insects from rotting wood, the camouflaging (= **cryptic**) color of a lizard against tree bark all have resulted from natural selection.

The raw material of these changes, of course, is non-lethal genetic **mutations**. The ancestors organisms alive today had mutations that might have made them slightly better "prepared" for survival in a changing environment than other members of their species (their **conspecifics**). Whoever had the most babies won the evolutionary contest!

In real life, natural selection isn't much fun if you're the loser. But today's demonstration should be fun, even though some of us will "go extinct." Today, we will become predators with a variety of different mouthparts, and our prey will be a species of bean that comes in four different colors. Natural selection, sometimes a double-edged sword, will work on both predator and prey. Let's see how it works.

Bean Camouflage vs. Predator Mouthparts

Many predators rely on visual cues to detect prey. Tasty prey items that are less conspicuous than equally tasty members of their population may have a **selective advantage** over their more visible conspecifics.

We will scatter a population of 600 *Beanus gooberensis*, consisting of equal numbers of four color **morphs** of *B. gooberensis*: 150 black, 150 white, 150 pinto, and 150 red. Which color of bean is best at hiding from predators? That's what we're going to find out.

We predators will play predators having one of five different kinds of specialized feeding structures: 5 tongs, 5 fork, 5 knife, 5 spoon and 5 chopsticks. Which type of predator is best able to find and handle bean prey? Stay tuned!

Before we begin, let's consider...

For the prey species:

What is your null hypothesis? _____

What is your alternative hypothesis? _____

For the predator species:

What is your null hypothesis? _____

What is your alternative hypothesis? _____

READ DIRECTIONS CAREFULLY BEFORE BEGINNING!

1. Dividing the labor among the class members, count out 150 individuals of each of the four available bean color morphs.
2. Place all beans together in the container your facilitator provides and shake well to mix them thoroughly.
3. Predators, arm yourselves! There should be equal numbers of predators equipped with each of the five types of feeding structures.
4. The group leader will scatter beans in a pre-determined area on the lawn. On the timer's mark, the predators begin foraging.
5. Predators will have 90 seconds to capture as many beans as possible and place them in their mouths (cups).
6. At the end of the 90 seconds, predators in each group will band together and count how many of each color bean they have captured.
7. When all predator teams are ready, the group leader will call out for the results from each group, and EVERYONE should write the results in Table 1.

PREDATOR RULES:

1. **Predators must pick up prey with their feeding apparatus only. No helping with fingers or other objects, including the cups!**
2. **Predators may not remove prey from a fellow predator's cup (eeyuck!), but they may feel free to dash in and fight for any prey being pursued by another predator. It's a jungle out there. Hungry predators are not kind to strangers.**

Ready? On your mark. Get set. GO!!! (Once the first round of bloody carnage is over, all groups return to the lab to count and digest their prey.) Use Table 1 to record the data for each bean color and predator type.

Step One: How many beans have survived to reproduce?

Now go to PAGE 5 and use Table 1 to compile your data. You'll use this table for all four generations, so try to keep it neat and readable as you add more data.

Each group of predators, when called by the group leader, should announce the number of each bean color caught. The leader will write these numbers on the board, and **everyone should write these numbers in Table 1.**

To calculate how many beans survived to reproduce, go to page 6 and use Table 2.

Finally, to calculate the number of new baby beans ("recruits") in the next generation, go to page 7 and use the calculation sheet for Generation II. (There are similar calculation sheets on the following pages for Generations III and IV.)

1. Count the number of *each color bean* killed by *each predator*, and enter in Table 1.
2. Subtract the number killed from 150 (your starting population) to get the number of survivors. Enter these numbers in the bottom row of the table.
3. For each bean color, **calculate the number of new beans to add to the population** with the formula shown in the work boxes on Page 7:

$$\frac{\text{\# of prey color survivors}}{\text{total \# of survivors (all colors)}} \times \text{total \# of prey killed (all colors)} = \text{\# of prey color for next generation}$$

This is an index of how many beans were left behind in the population to have babies.

Step Two: How many predators have survived to reproduce?

Ah, Natural Selection. It's a sharp sword, and it cuts both ways. Predators, too, have experienced differential success in this game, and that means differential reproduction. (The more food you get, the more babies you can have.) As you will see, some feeding structures are better suited for capturing beans than others.

1. Predator groups should band together again and calculate the total number of beans (all colors) killed by their type of predator. (You can calculate this for each predator type by using the data you've already entered in Table 1.)
2. Add the totals together to determine overall total # of beans killed. Use Table 1.
4. With this information, you can calculate how many predators of each type will exist in the next generation of predators with the following formula:

$$\frac{\text{total \# beans killed by predator type}}{\text{total \# beans killed by all predators}} \times \text{total number of all predators} = \text{\# of predator type in next generation}$$

On page 8 (and subsequent pages for Generations III and IV), you'll find work boxes with this formula that will allow you to calculate your predator population for the next generation. Go there now and calculate!

Round Two, and Beyond!

After you have determined the composition of the next generation of predators and prey, count the correct number of new bean **recruits** to be added to the existing population. The group leader will scatter prey on the lawn in the same habitat we hunted before, and the predators will set upon them once more for 90 seconds.

Repeat the calculations for predators and prey as above, and do as many generations as time permits. Use Tables 1 and 2 to record your data. Use the extra calculation sheets provided for both predators and prey for each Generation (pp 7 – 12).

REMEMBER THAT THE NUMBER OF BEANS OF EACH COLOR WILL CHANGE IN EACH GENERATION, BECAUSE EACH COLOR HAS DIFFERENT MORTALITY AND SURVIVORSHIP. When you add your **new recruits** to the population, add it to the **survivors** of the previous generation to get the correct **total number of beans of each color** for your calculations. Obviously, you won't have 150 of each color in each generation, because some of the beans are escaping better than others. But there should be 600 beans in each generation; only the color proportions should change.

Graphing Your Data

Once you have completed several generations of predation, plot the results of predator and prey population changes on a graph. We'll let you decide whether to use a polygon or a histogram, but one is definitely more appropriate than the other for these data.

What do the graphs tell you about the predators and prey, and their relative fitness compared to their conspecifics (i.e., members of their own species)?

THOUGHT QUESTIONS

1. Which color prey seem to be the best adapted to this lawn environment and its predators? Which is the least adapted? Explain.
2. Which predators seem to be best adapted to exploit this bean-rich environment? Which is the least adapted? Explain.
3. Can you think of any factors besides bean color which could have affected the bean survival? Do you think that only one phenotypic character is primarily responsible for survival in a complex environment? Why or why not?
4. Can you think of any factors besides type of feeding apparatus which might contribute to an individual predator's success (i.e., Were any of the predators more aggressive than others? Did any have better or poorer eyesight than the others?) What other phenotypic trait might contribute to a predator's survival (and, by association, potential time and energy to engage in some reproductive fitness) in this population?
5. Did any predator or prey type become extinct? Why or why not? If none went extinct, would you predict that any might go extinct over more generations? Which ones and why?
6. Did the experimental results support or refute your null hypothesis? Can you devise a new hypothesis in light of your results? What further tests might you perform on these populations if someone held a cattle prod against your rump and forced you?

Table 1. Predator Foraging Success vs. Bean Survival

Generation I:

predator	black	white	pinto	red	TOTAL
spoon					
tongs					
fork					
chopsticks					
knife					
Starting # beans	150	150	150	150	600
bean kills					
bean survivors					

Generation II:

predator	black	white	pinto	red	TOTAL
spoon					
tongs					
fork					
chopsticks					
knife					
Starting # beans					600
bean kills					
bean survivors					

Generation III:

predator	black	white	pinto	red	TOTAL
spoon					
tongs					
fork					
chopsticks					
knife					
Starting # beans					600
bean kills					
bean survivors					

Generation IV:

predator	black	white	pinto	red	TOTAL
spoon					
tongs					
fork					
chopsticks					
knife					
Starting # beans					600
bean kills					
bean survivors					

starting # beans: For Gen I, this is 150. For all subsequent generations, this is the # of survivors PLUS the number of recruits for each bean color.

bean kills = the sum of the numbers in the vertical column (bean color).

bean survivors = starting # of beans MINUS the # of bean kills (Use Table 2, page 6 for this.)

Table 2. Changes in Bean Prey Population

Starting Generation:

prey generation	black	white	pinto	red	TOTAL
I: total	150	150	150	150	600

Generation II: After the first round of hunting, fill in...

prey generation	black	white	pinto	red	TOTAL
a: # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					600

Use the work boxes on page 7 to calculate the # of new baby beans (recruits) to add to your surviving population in the grass. This will be Generation II.

Generation III: After the second round of hunting, fill in...

prey generation	black	white	pinto	red	TOTAL
a: # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					600

Use the formula on page 9 to calculate the # of new baby beans (recruits) to add to your surviving population in the grass. This will be Generation III.

Generation IV: After the third round of hunting, fill in...

prey generation	black	white	pinto	red	TOTAL
a. # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					600

Use the formula on page 11 to calculate the # of new baby beans (recruits) to add to your surviving population in the grass. This will be Generation IV.

Generation V: After the third round of hunting, fill in...

prey generation	black	white	pinto	red	TOTAL
a. # of kills					
b. # of survivors					
c. # of recruits					
# beans next Gen (b + c)					600

Use the formula on page 11 to calculate the # of new baby beans (recruits) to add to your surviving population in the grass. This will be Generation V.

GENERATION II: CALCULATING THE # OF NEW BABY BEANS

Use the spaces below to calculate the number of each color bean in the Generation II.

a. black beans:

$\frac{\text{\# of black survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new black beans added to the population ("recruits")}$

Do your calculation for the **black** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

b. white beans:

$\frac{\text{\# of white survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new white beans added to the population ("recruits")}$

Do your calculation for the **white** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

c. pinto beans:

$\frac{\text{\# of pinto survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new pinto beans added to the population ("recruits")}$

Do your calculation for the **pinto** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

d. red beans:

$\frac{\text{\# of red survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new red beans added to the population ("recruits")}$

Do your calculation for the **red** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

Once the numbers of new baby beans of each color have been calculated, volunteers will count up the correct number of each color, and add them to the Baby Bean Bin. These will be taken outside and added to the surviving bean population for the next round of predation.

GENERATION II: CALCULATING THE # OF PREDATORS

Use the spaces below to calculate the number of each predator type in the Generation II:

a. spoons:

$$\frac{\text{\# of beans killed by spoons}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\# of spoons in the second generation}$$

Do your calculation for the **spoons** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of spoons in next round)}}$$

b. tongs:

$$\frac{\text{\# of beans killed by tongs}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\# of tongs in the second generation}$$

Do your calculation for the **tongs** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of tongs in next round)}}$$

c. forks:

$$\frac{\text{\# of beans killed by forks}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\# of forks in the second generation}$$

Do your calculation for the **forks** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of forks in next round)}}$$

d. chopsticks:

$$\frac{\text{\# of beans killed by chopsticks}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\# of chopsticks in the second generation}$$

Do your calculation for the **chopsticks** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of chopsticks in next round)}}$$

e. knives:

$$\frac{\text{\# of beans killed by knives}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\# of knives in the second generation}$$

Do your calculation for the **knives** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of knives in next round)}}$$

Once each predator group has finished its calculations, establish your new predator populations. If a predator's number has decreased (for example, if chopsticks went from 5 to 3), the correct number of members of the decreased group must give up their mouthparts, and become a different type of predator (in a more successful group whose numbers have increased).

GENERATION III: CALCULATING THE # OF NEW BABY BEANS

a. black beans:

$$\frac{\text{\# of black survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new black beans added to the population}$$

Do your calculation for the **black** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

b. white beans:

$$\frac{\text{\# of white survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new white beans added to the population ("recruits")}$$

Do your calculation for the **white** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

c. pinto beans:

$$\frac{\text{\# of pinto survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new pinto beans added to the population ("recruits")}$$

Do your calculation for the **pinto** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

d. red beans:

$$\frac{\text{\# of red survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new red beans added to the population ("recruits")}$$

Do your calculation for the **red** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

GENERATION III: CALCULATING THE # OF PREDATORS

a. spoons:

$$\frac{\text{\# of beans killed by spoons}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\#of spoons in the next generation}$$

Do your calculation for the **spoons** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of spoons for next round)}}$$

b. tongs:

$$\frac{\text{\# of beans killed by tongs}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\#of tongs in the next generation}$$

Do your calculation for the **tongs** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of tongs for next round)}}$$

c. forks:

$$\frac{\text{\# of beans killed by forks}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of forks in the next generation}$$

Do your calculation for the **forks** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of forks for next round)}}$$

d. chopsticks:

$$\frac{\text{\# of beans killed by chopsticks}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of chopsticks in the next generation}$$

Do your calculation for the **chopsticks** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of chopsticks for next round)}}$$

e. knives:

$$\frac{\text{\# of beans killed by knives}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of knives in the next generation}$$

Do your calculation for the **knives** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of knives for next round)}}$$

GENERATION IV: CALCULATING THE # OF NEW BABY BEANS

a. black beans:

$$\frac{\text{\# of black survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new black beans added to the population}$$

Do your calculation for the **black** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

b. white beans:

$$\frac{\text{\# of white survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new white beans added to the population ("recruits")}$$

Do your calculation for the **white** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

c. pinto beans:

$$\frac{\text{\# of pinto survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new pinto beans added to the population ("recruits")}$$

Do your calculation for the **pinto** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

d. red beans:

$$\frac{\text{\# of red survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new red beans added to the population ("recruits")}$$

Do your calculation for the **red** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

GENERATION IV: CALCULATING THE # OF PREDATORS

a. spoons:

$$\frac{\text{\# of beans killed by spoons}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\#of spoons in the next generation}$$

Do your calculation for the **spoons** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of spoons for next round)}}$$

b. tongs:

$$\frac{\text{\# of beans killed by tongs}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\#of tongs in the next generation}$$

Do your calculation for the **tongs** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of tongs for next round)}}$$

c. forks:

$$\frac{\text{\# of beans killed by forks}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of forks in the next generation}$$

Do your calculation for the **forks** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of forks for next round)}}$$

d. chopsticks:

$$\frac{\text{\# of beans killed by chopsticks}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of chopsticks in the next generation}$$

Do your calculation for the **chopsticks** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of chopsticks for next round)}}$$

e. knives:

$$\frac{\text{\# of beans killed by knives}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of knives in the next generation}$$

Do your calculation for the **knives** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of knives for next round)}}$$

GENERATION V: CALCULATING THE # OF NEW BABY BEANS

a. black beans:

$$\frac{\text{\# of black survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new black beans added to the population}$$

Do your calculation for the **black** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

b. white beans:

$$\frac{\text{\# of white survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new white beans added to the population ("recruits")}$$

Do your calculation for the **white** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

c. pinto beans:

$$\frac{\text{\# of pinto survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new pinto beans added to the population ("recruits")}$$

Do your calculation for the **pinto** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

d. red beans:

$$\frac{\text{\# of red survivors}}{\text{total \# of survivors(all colors)}} \times \text{total \# of beans killed} = \text{\#of new red beans added to the population ("recruits")}$$

Do your calculation for the **red** beans here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \underline{\hspace{2cm}} \text{ ("recruits")}$$

GENERATION V: CALCULATING THE # OF NEW BABY BEANS

a. spoons:

$$\frac{\text{\# of beans killed by spoons}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\#of spoons in the next generation}$$

Do your calculation for the **spoons** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of spoons for next round)}}$$

b. tongs:

$$\frac{\text{\# of beans killed by tongs}}{\text{total \# of beans killed}} \times \text{total \# of predators (all types)} = \text{\#of tongs in the next generation}$$

Do your calculation for the **tongs** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of tongs for next round)}}$$

c. forks:

$$\frac{\text{\# of beans killed by forks}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of forks in the next generation}$$

Do your calculation for the **forks** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of forks for next round)}}$$

d. chopsticks:

$$\frac{\text{\# of beans killed by chopsticks}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of chopsticks in the next generation}$$

Do your calculation for the **chopsticks** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of chopsticks for next round)}}$$

e. knives:

$$\frac{\text{\# of beans killed by knives}}{\text{total \# of beans killed}} \times \text{total \# of predators} = \text{\#of knives in the next generation}$$

Do your calculation for the **knives** here:

$$\frac{(\quad)}{(\quad)} \times (\quad) = \frac{\quad}{\text{(\# of knives for next round)}}$$